Postharvest quality of refrigerated tomato fruit (*Solanum lycopersicum*, cv. Zinac) at two maturity stages following heat treatment

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Introduction

The increasing demand for tomato fruits cleaned, healthy, tasteful, nutritive and with longer shelf-life, led to the development and use of numerous effective preservation non-chemical methods. There is much interest in developing safer and more effective sanitizers for fruit and vegetable, and heat treatments (HT) appear to be one of the most promising postharvest treatments [1] (Boukobza and Taylor, 2002).

The aim of this work was to evaluate the effect of an optimized water heat treatment (WHT - 40 ºC for 30 min [2] Pinheiro et al. 2012) on the tomato (*Solanum lycopersicum*, cv. Zinac) quality attributes at two maturity stages (turning and pink), followed by storage at 10 ºC during 14 days.

Materials & methods

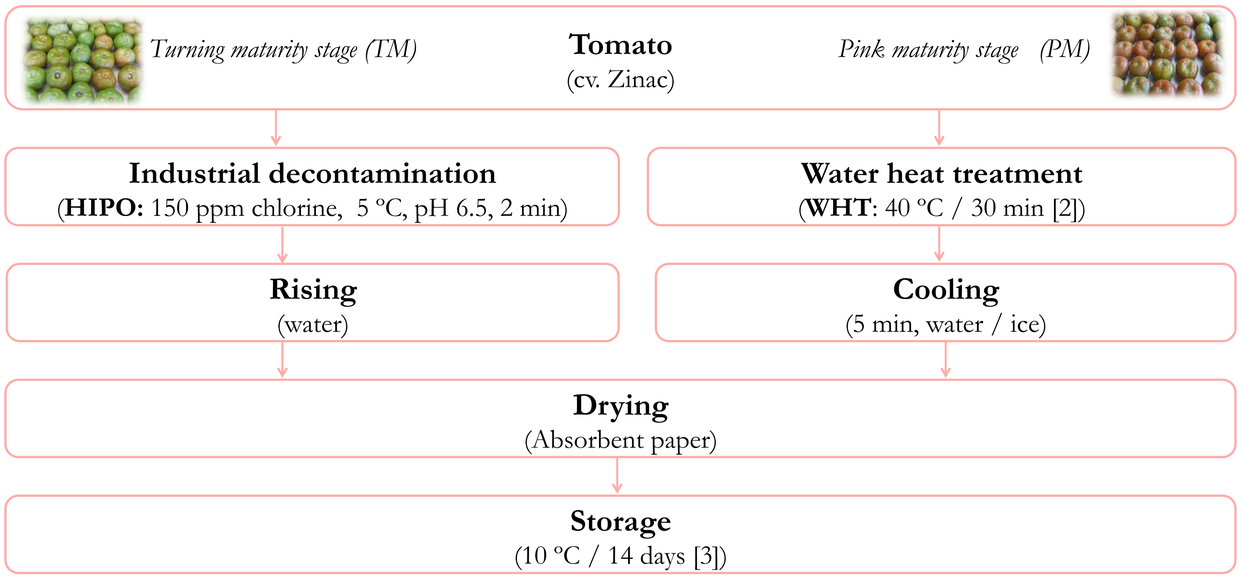


Fig. 1 - Experimental set-up for control samples (HIPO) and water heat treated (WHT) tomato fruits at two maturity stages: turning (TM) and pink (PM).

Quality attributes: pH, soluble solids content (SSC), firmness, colour, peroxidase (POD) [4] and pectin methyl esterase (PME) [5], mesophylic count [6], yeasts and moulds (Y&M) [7].

Data analysis: variance (two and multi-effects ANOVA) using a Statistica version 7.0 software [8] (Statsoft 2004). The Fisher Least Significant Difference (LSD) test was used to determine significant differences ($P<0.05$) between samples. Pearson correlation coefficients were also generated between the studied quality attributes. In order to predict stored tomato behavior and determine its shelf-life, colour and firmness data was modeled by first order kinetic model (Eq. 1), where C is the measured quality factor (a/b or firmness), the index 0 indicates the initial value, t is the storage time, and k the rate constant at constant temperature 10ºC.

$$C = C_0\, e^{-kt} \quad \textbf{(Eq. 1)}$$

Results

1. Characterization of tomato fruits

	HIPO		WHT	
Quality attributes	**Turning**	**Pink**	**Turning**	**Pink**
Physical-chemical				
pH	4.3^{a}±0.05	4.3^{a}±0.04	4.3^{a}±0.06	4.3^{a}±0.01
TSS (º Brix)	3.3^{a}±0.05	3.9^{d}±0.06	4.6^{b}±0.1	4.2^{c}±0.01
Firmness (N)	11.6^{b}±1.2	8.7^{a}±1.2	10.6^{b}±1.4	8.3^{a}±0.8
Color parameters				
L*	48.9^{b}±2.4	48.6^{a,b}±3.3	52.1^{c}±2.9	46.9^{a}±3.4
a*/b*	-0.3^{a}±1.1	0.09^{b}±1.3	-0.3^{a}±1.3	0.02^{b}±0.9
Hue (ºh))	106.1^{b}±8.5	85.4^{a}±10.6	105.2^{b}±9.2	88.7^{a}±8.3
Biochemical				
POD activity (Abs.min.ml^{-1})	5.4^{c}±0.9	2.6^{a}±0.2	6.7^{d}±0.1	3.7^{b}±0.4
PME activity (Abs.min.ml^{-1})	2.0^{a}±0.4	2.5^{b}±0.3	2.9^{b}±0.5	1.7^{a}±0.1
Microbial load				
Mesophylic [Log_{10} (cfu.g^{-1})]	4.9^{a}±1.6	4.9^{a}±1.6	1.8^{b}±0.8	3.6^{a}±0.4
Yeasts and moulds [Log_{10} (cfu.g^{-1})]	3.4^{a}±0.4	3.4^{a}±0.4	1.5^{b}±0.4	0.0^{c}±0.0

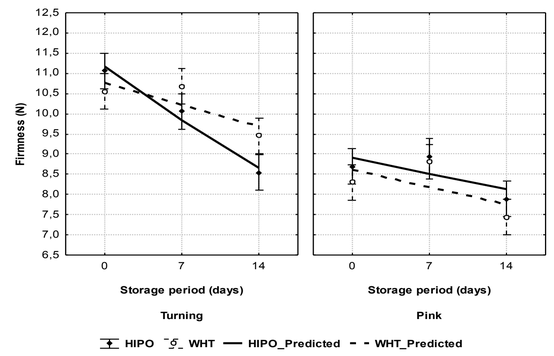
In the same line, different letters represent significant differences at P<0.05

- The efficacy of chlorine treatment to reduce microbial population was about of 1.3 and 1.1 Log_{10}, on **mesophylic** and **Y&M load**, respectively in both maturity stages.

- **pH and TSS** for the two tomato maturity stages were not significantly different ($P > 0.05$).
- **TSS values** of TM_WHT samples were higher ($P<0.05$) than TM_HIPO samples.
- Tomato **colour** parameters a*/b* and ºh differ significantly ($P<0.05$) between both maturity stages. The applied WHT did not change tomato colour compared with HIPO samples.
- As expected, tomato **firmness** differs significantly ($P<0.05$) between both maturity stages.
- **POD activity** in TM tomato is significantly higher than in PM tomato (~50%, $P<0.05$). After treatments, the applied WHT contributed to a significant increase ($P<0.05$) of POD activity, *ca.* 22.8% and 45.6% on TM and PM heat treated samples, respectively.
- **PME activity** was significantly lower ($P<0.05$) in TM tomato than in PM tomato (~35%, $P<0.05$). Initial PME values were significantly higher ($P<0.05$) for TM_WHT samples as compared to the TM_HIPO samples, achieving a partial activation of 43.3 %.

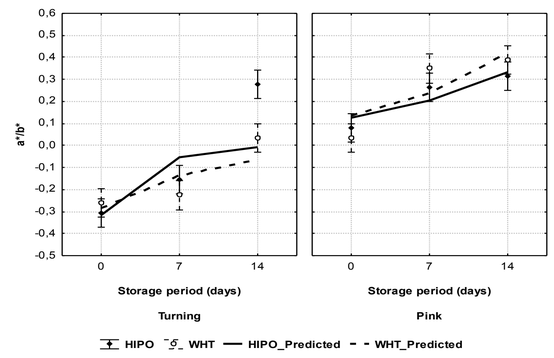
Results

2. Firmness



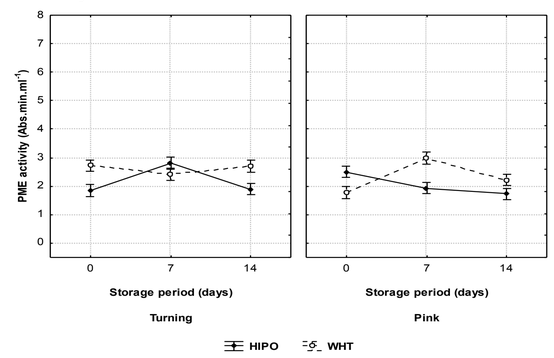
- Differences in firmness decreases were observed between treatments. After ca. 3 days, firmness of TM_HIPO samples is lost more rapidly, showing a decrease of 13% compared to initial value. Conversely, at the end of storage, WHT samples had slightly higher firmness (more 11%).
- No significant difference ($P>0.05$) was found among the treatments (HIPO x WHT) in PM tomato samples.
- Firmness of both treatment (HIPO and WHT) and maturity stage samples decreased ca. 26.4, 10.4 and 9.2, 10.5%, for TM and PM samples, respectively.

3. Colour



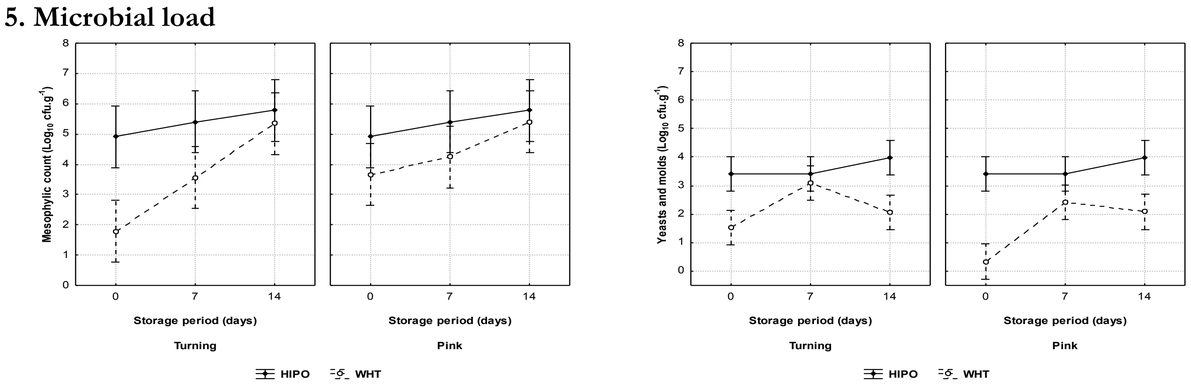
- During storage, a*/b* values for both TM tomato treated samples increased steadily and significantly ($P<0.05$) until the end of storage, 0.5 and 0.3 units for HIPO and WHT, respectively.
- The a*/b* color parameter of PM_WHT sample also increased, became more red with the storage time. However, this increase was not significant ($P>0.05$) due to dispersion of the measured values, revealing a non uniform color development.

4. Enzymatic activities



- Turning HIPO samples observed a significant increase in PME activity reaching highest activity by day 7 (2.8 Abs.mim.ml-1), followed by a decrease to the end of storage period. Regarding the PME activity level of TM_WHT samples, it was maintained throughout the storage (2.81 Abs.min.ml-1, $P>0.05$).
- In PM tomato samples opposing behavior was observed. In WHT samples there was an increase in PME activity at day 7 (76.8%) followed by a significantly decrease in activity (25.8%) to the end (day 14). PME activity of PM_HIPO samples decreased uniformly during storage.
- In both fruits maturity stages, WHT tomato maintained the initial POD activity level until day 7, followed by a decrease up to the end (day 14). Nevertheless, by the end of storage, TM_WHT samples registered a higher POD activity (more 70%, $P<0.05$) than the respective control (HIPO samples).
- An exception to the decrease behavior of POD activity during storage was observed in TM_HIPO samples, where an increase in POD levels was found from day 0 to 7.

5. Microbial load



- At the end of storage, all WHT samples had lower counts of mesophylic and Y&M flora, revealing that WHT at 40 ºC - 30 min can be used to improve tomato shelf-life.

6. Kinetic data and shelf-life determination

- Taking into account the firmness criteria for tomato 'cv. Zinac' shelf life (4.2 N; [3]) and the prediction based on Eq. 1 and kinetic parameters, the HIPO and WHT samples at TM and PM stage required approximately 24, 51 and 50, 43 days at 10ºC, respectively.
- The WHT at 40 ºC / 30 min was effective to prolong twice as long the predicted storage period compared with HIPO treatment at TM tomato.

Kinetic parameters and corresponding confidence intervals at 95% for a*/b* and firmness of tomato HIPO and WHT at two maturity stages

Maturity stages	Treatment	*a*/b**	Firmness (N)
Turning	HIPO	$C_0 = -0.32 \pm 0.12$	$C_0 = 11.16 \pm 0.52$
		$k_{10ºC}$ (day^{-1}) $= 0.25 \pm 0.32$	$k_{10ºC}$ (day^{-1}) $= 0.02 \pm 0.006$
	WHT	$C_0 = -0.28 \pm 0.11$	$C_0 = 10.77 \pm 0.69$
		$k_{10ºC}$ (day^{-1}) $= 0.11 \pm 0.10$	$k_{10ºC}$ (day^{-1}) $= 0.01 \pm 0.01$
Pink	HIPO	$C_0 = 0.13 \pm 0.07$	$C_0 = 8.90 \pm 0.43$
		$k_{10ºC}$ (day^{-1}) $= -0.07 \pm 0.05$	$k_{10ºC}$ (day^{-1}) $= 0.01 \pm 0.01$
	WHT	$C_0 = 0.13 \pm 0.07$	$C_0 = 8.60 \pm 0.72$
		$k_{10ºC}$ (day^{-1}) $= -0.08 \pm 0.04$	$k_{10ºC}$ (day^{-1}) $= 0.01 \pm 0.01$

Conclusions

Our results provide strong evidence that postharvest water heat treatment (40 ºC - 30 min) for tomato fruits (cv. 'Zinac') at turning maturity stage guarantees the overall quality at 10 ºC, twice as long of fruits washed with chlorinated water.

References: [1] BOUKOBZA, F. and TAYLOR, A.J. 2002. Effect of postharvest treatment on flavour volatiles of tomatoes. Postharvest Biol. Technol. 25, 321–331. [2] PINHEIRO, J., SILVA, C.L.M., ALEGRIA, C., ABREU, M., SOL, M. and GONÇALVES, E.M. 2012. Impact of water heat treatment on physical-chemical, biochemical and microbiological quality of whole tomato (*Solanum lycopersicum*) fruit. Acta Horticulturae (ISHS) 934, 1269-1276. [3] PINHEIRO, J., ALEGRIA, C., ABREU, M., GONÇALVES, E.M. and SILVA, C.L.M. 2013. Kinetics of changes in the physical quality parameters of fresh tomato fruits (*Solanum lycopersicum*, cv 'Zinac') during storage. J. Food Eng. 114, 338-345. [4] YAHIA, E.M., SOTO-ZAMORA, G., BRECHT, J.K. and GARDEA, A. 2007. Postharvest hot air treatment effects on the antioxidant system in stored mature-green tomatoes. Postharvest Biol. Technol. 44(2), 107-15. [5] HAGERMAN A.E. and AUSTIN P.J. 1986. Continuous spectrophotometric assay for plant pectin methylesterase. J. Agr. Food Chem. 34(3), 440-444. [6] ISO 4833. 2003. Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of microorganisms - Colony-count technique at 30 degrees C. [7] NP 3277. 1987. Microbiologia alimentar. Contagem de bolores e leveduras. Parte 1: Incubação a 37 °C. [8] STATSOFT, Inc. 2004. STATISTICA (data analysis software system), version 7. www.statsoft.com.

Acknowledgements: The author Joaquina Pinheiro would like to thank Fundação para a Ciência e a Tecnologia (PhD grant SFRH/BD/24913/2005).